

# Data capture using vectorization of satellite images and maps to serve change detection

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The increasing availability of remote-sensing images, acquired periodically by satellite sensors on the same geographical area, makes it extremely interesting to develop monitoring systems capable of automatically producing and regularly updating land-cover maps of the considered site. The fast and big changes in ground features needs to quick and fast way for updating maps to suit the flow huge varying of data from satellite images, this data can be benefit in updating maps. The primary objective of this research is to detect changes in man-made objects such as building using IKONOS image in order to update GIS layer. The main goal of this research is on the extraction of linear features from satellite images by using vectorization. The data used of this research is cadastral map of scale 1:5000 of year 1994 besides IKONOS image with resolution 4 ms of the same region of year 1999 to detect the data changes during this period. In this paper, attention was restricted to the decreasing of agriculture lands, so the remote sensing software (ER Mapper) was used to vectorization the image and the GIS software (ARC/INFO) was used to perform some operation (e.g. overlay ) to detect the changes.

إن التوفر المتزايد لصور الأقمار الصناعية وجودها بشكل دوري لنفس المنطقة، يجعل من الأهمية تطوير أنظمة مراقبة الية قادرة على إنتاج وتحديث الخرائط بصورة دورية. إن التغير الكبير والسريع في المعالم الطبيعية يلزمه طريقة سريعة لتحديث الخرائط لتوائم هذا التغيير المصاحب للكم الكبير من المعلومات المتدفق من صور الأقمار الصناعية والذي يمكن الاستفادة منها في تحديث الخرائط. والهدف الأساسي من هذا البحث هو تحديد التغيرات التي تحدث بواسطة الإنسان مثل المباني باستخدام صورة من القمر الصناعي IKONOS حتى يمكن استخدام هذه البيانات كطبقات في نظم المعلومات الجغرافية باستخدام عملية تحويل صور الأقمار الصناعية إلى بيانات خطية. حيث تم استخدام خريطة مقياس 1:5000 تصوير جوى لسنة 1994 مع صورة للقمر الصناعي IKONOS بدقة هندسية 4 م لنقش المنطقة لسنة 1999 وذلك لملاحظة التغير الحادث في البيانات خلال هذه الفترة الزمنية حيث تم ملاحظة الزحف العمراني والنقص المقابل في مساحة الأرض المنزرعة حيث تم عمل تقييم لمساحات الاراضى المنزرعة في الخريطة 1:5000 وكذلك عمل تحويل للبيانات الرقمية في الصورة إلى بيانات خطية مع اعتبار المساحات المنزرعة فقط وتم استخدام برنامج متخصص فالإستشعار عن بعد وبرنامج اخر متخصص في نظم المعلومات الجغرافية لإجراء عملية التوافق بين مصدرى البيانات وعمل Overlay لهما مع طرح البيانات من بعضها والتي ينتج عنها المساحات التي حدث فيها تغيير والتي يمكن استخدامها في تحديث الخرائط.

**Keywords:** Vectorization, GIS, Remote sensing, Classification

## 1. Introduction

Maps are vital tools for most government agencies and consumers. However, their manual generation and updating is tedious, time consuming, and expensive. To address these concerns, we are developing automated techniques. In this paper, we restrict our attention to residential regions, such regions are also typically areas of rapid growth and development. As the next step toward automatic map generation, here we introduce a system to detect residential area in IKONOS multispectral images. These images have 4 m resolution in the spectral bands [1].

The demand for rapid mapping operations such as updating is continuously increasing. Image analysis techniques have been investigated and tested in this study to introduce automation in the assessment of digitized maps and IKONOS multispectral imagery for feature separation and extraction. A raster to vector approach (R /V) followed for the vectorization of these extracted features. Following the analysis of the map and image data, change detection between two datasets was performed [2].

Most of the research in remote sensing is focused on developing well-defined and reliable automated processes for the

extraction of information from different types of imagery. In this communication, we are dealing with the extraction of linear man-made objects (especially buildings) in urban areas and the determination of changes in these objects using very high resolution IKONOS imagery.

The modern world needs accurate information about these changes for updating Geospatial Information Systems (GIS) and databases. The updated GIS information is utilized for important applications such as: city planning, industrial planning, road networking, property evaluation, disaster management and so on [3].

## 2. Background

The extraction of man-made objects located in heterogeneous urban areas is a very difficult task due to the presence of different types of objects such as trees, large size containers, roads, parking lots. To discriminate the object of interest from the other objects, a pre-processing of the temporal images is necessary. This pre-processing can be based on image classification utilizing the spectral response property of each of the objects. For example, spectral reflectance of vegetation is high in the region of 0.75- 1.35  $\mu$ m and spectral reflectance of rocks and construction material used for the buildings is high in the region range of 2.0-2.5  $\mu$ m. Hence it is possible to discriminate buildings from the vegetation based on the spectral reflectance property [3].

### 2.1. Change detection

Change detection is a process of identifying differences in the state of object or phenomena by observing them at different times.

Change detection of man-made objects gives information about newly constructed buildings, parks, roads that is useful for determining approximate increase in population or industrial area. This information is useful to determine needs of new parking lots, malls or schools for an urban area.

For a detailed understanding of the pros and cons of the existing techniques of change

detection, the existing change detection techniques are categorized into three groups: Image to Image, Image to GIS layer and Image to Geometric Site Model change detection.

#### 2.1.1. Image to image change detection

Techniques use temporal geo-referenced images as an input for the detection of the change. There are several methods of Image to Image change detection (Spectral Change Detection Technique).

Spectral change detection methods are as follows:

- *Image differencing*: Image differencing is one of the simplest digital algorithms for change detection. Image differencing means taking an image at one time and subtracting it from another image from a later time. The resultant image represents changes between the two dates. For example, each 8-bit band has digital values ranging from 0 to 255; the total potential range of the difference image is -255 to +255. Usually, a constant is added to the resulting value so that all differences are positive. Pixels exhibiting a significant radiance change are expected to lie in the tails of the distributions of the difference image, whereas the unchanged pixels should be grouped about the mean
- *Image ratioing*: Like the previous method, two co-registered image dates are ratioed pixel by pixel in each band. The no-change area is characterized by ratio values close to 1. Depending on the nature of changes between two dates changed areas will have higher or lower values.
- *Image regression*: This method assumes that pixels from time t1 to be a linear feature of time t2 pixels. It considers differences in mean and variance between pixel values from two dates.
- *Change vector analysis*: The vector difference between the multi-band digital vector of the pixel on two different dates.. A spectral change vector describes direction and magnitude of change from date one to date two. The output encompasses two images, one containing the magnitude of the change vector, the other its direction. Comparison of magnitude of changes with a specified threshold determines the change (if exceeds)

and direction of change vector represents the type of change.

- *Vegetation index differencing:* In vegetation studies the ratio (known as vegetation indices) is used to enhance the spectral differences between strong reflectance of vegetation in the near-infrared part of spectrum and chlorophyll-absorption band (red part) of the spectrum.
- *Multi-date principal component Analysis:* In multi-date principal component, two image dates of the same area are superimposed and analysed as a single image. Yuan et al. reported that the major component images show the albedo (reflectance) and radiometric differences, and that minor component images reveal the local changes (minor changes). Li and Yeh reported the usefulness of this method to monitor rapid land-use changes and urban expansion in comparison with post classification method.
- *Post-classification technique:* In the post-classification approach, images belonging to different dates are classified and labeled individually. Later, the classification results are compared directly and the area of changes extracted.

#### 2.1.2. Image to site model type methods

Compare the object of interest extracted from the image with its geometric model. For the change detection of buildings, geometric models of building are developed using geophysical information such as number of corner points, number of edges connecting those corner points, position, height, size and shape of the building.

#### 2.1.3. The image to GIS change detection method

Compares the extracted features with the feature of interest from GIS layers. For a direct comparison the features from GIS layer need to be converted into raster format. Then the derived changed information is obtained using feature matching technique. The process of change detection of man-made objects consists of three major steps: image registration, feature (object of interest) extraction and detection of geometric differences in the extracted features from the temporal images of the same location [3].

## 2.2. Supervised classification

Supervised classification method is suitable for classification of the images using spectral information. One can classify man-made objects such as roads and buildings using spectral signature. This information is useful for the preliminary change detection. The preliminary change detection approach is a semiautomatic method. It is based on the classification of pixels of multispectral images using detailed and a priori knowledge about the area of interest. Classifying multispectral images for preliminary change detection consists of drawing boundaries around geographically located classes that are homogeneous or acceptably heterogeneous, and of describing those classes with their attributes and their relations in a consistent and logical manner [3].

## 2.3. Data structure

The two basic data structures that are used for storing and manipulating images and graphics on a computer are raster and vector data models. All of the major Geographic Information Systems (GIS) and Computer Aided Design (CAD) software packages available today are mainly based on one of the two data structures, either raster or vector [4].

### 2.3.1. Raster data

Raster data can be defined as an abstraction of the real world where spatial data is expressed as a matrix of cells or pixels, with spatial position implicit in the ordering of the pixels. The pixel value indicates the attribute, such as color, elevation, or ID number. Since the raster image is made of pixels, the spatial locations of the objects are represented by its spatial resolution. If the spatial resolution is increased by 2 times then the total size of a two-dimensional raster image will increase by 4 times because the number of pixels is doubled in both X and Y dimensions. In such cases the image becomes more and more rough, while zooming in [4].

### 2.3.2. Vector data

Vector data, when used in the context of spatial or map information, refers to a format

where map information is stored as points (node), lines (polylines) or polygons (areas). Vector data are geometrically and mathematically associated. Points are stored using the coordinates. Lines are stored as a series of point pairs, where each pair represents a straight line segment. Vector data has topological relationship, location and attribute information associated with it. Attributes are used to describe the map information represented by a point, line, or polygon [4].

### 2.3.3. Raster to vector conversion methods

Vector data is normally created from existing paper maps or natural source images, such as aerial photographs or satellite imagery. Vector data has traditionally been acquired by manual digitization. Manual digitization can be split into two categories, table top digitizing and overlay digitizing. Table top digitizing is a fully manual method. In this method an operator uses a digitizing table with a hard copy map affixed to its surface. The operator registers its co-ordinates and proceeds to trace the map using a digitizing cursor which interacts with the table's surface. Using this information a representation of the map in vector form is generated. The disadvantage of manual digitizing is that it can be time consuming and it also can be less accurate, the main reason being that a human eye has the capacity of distinguishing only 40 dots per inch (DPI).

Overlay digitizing was seen as a temporary solution. It was developed when many GIS systems began to support raster images as back drops. This allowed digitizing on-screen by marking out elements using the screen cursor. One of the advantages of this method was that the operator could zoom and pan the image to distinguish between lines or areas. Most of the semiautomatic techniques use line tracing algorithms. The user adds vertices where the direction of the line changes. Fully Automated Techniques that convert raster-to-vector were assumed to be the next step in GIS data capture. However, the expectation for a definitive solution faded in the face of the richness and complexity of geographic and engineering information held on maps and plans. Nearly all GIS applications require

some of their basic data to be in vector form [4].

Raster to vector conversion, sometimes called vectorization, allows you to convert data from a raster data structure to a vector data structure. For example, features or thematic classes defined by processing a satellite image can be converted to polylines and polygons, and then imported directly into a vector-based GIS product or used for further processing of raster data. Raster to vector conversion is an especially valuable feature for extracting timely information from satellite images to quickly update vector-based information stored in GIS products [5].

### 2.4. Thresholding

Thresholding is used to separate the regions of the image corresponding to an object from its background. Thresholding is a very convenient way of performing segmentation.

Thresholding can be defined as an image processing function that is used to segment an image by setting all pixels whose intensity values are above a threshold to a foreground value and the remaining pixels to a background value. It can also be used to see what areas of an image consist of pixels whose values lie within a specified range, or band of intensities (or colors).

The input to a thresholding operation is typically a grayscale or color image. In the simplest implementation, the output is a binary image representing the segmentation. Black pixels correspond to background and white pixels correspond to foreground (or vice versa). In simple implementations, the segmentation is determined by a single parameter known as the intensity threshold. In a single pass, each pixel in the image is compared with this threshold. If the pixel's intensity is higher than the threshold, the pixel is set to white in the output. If it is less than the threshold, it is set to black. This method is called global thresholding. In more sophisticated implementations, multiple thresholds can be specified, allowing a band of intensity values to be set to white while everything else is set to black. For color or multi-spectral images, it may be possible to

set different thresholds for each color channel, and so select just those pixels within a specified cuboid in the RGB space. Another common variant is to set to black all those pixels corresponding to background, but leave foreground pixels at their original color/intensity (as opposed to forcing them to white), so that the information is not lost. This method is called local thresholding [4].

### 3. Methodology

The data sets used for this research are:

- The Ikonos multispectral imagery (4 metre spatial resolution) of year 1999 acquired over the portion of Cairo City, Egypt fig. 1.
- The layer of interest from the digitizing the interest features from cadastral map of scale 1:5000 for the same area of year 1994 fig. 2.



Fig. 1. Ikonos multispectral image.



Fig. 2. Cadastral map of scale 1:5000.

The basic steps of methodology (Algorithm) involve:

1. Digitization of the original paper document using overlay digitizing
2. Registration
3. Classification of image
4. Filtering
5. Thresholding
6. Raster to vector conversion.
7. Import the two data set to ARC/INFO
8. Build topology
9. Perform overlay operation

The original paper document was digitized – considering agriculture land only – the output of this operation as shown in fig. 3.

Registration is simply aligning two images so they can be overlaid or superimposed for comparison. In this case, the images do not have to be rectified to a map projection (they can both be in a "raw" coordinate system).

By using one type of different types of ER Mapper's rectification, the image was rectified. In the classification step, program searches for natural groupings or clusters of the spectral properties of pixels, and assigns each pixel to a class based on defined initial clustering parameters previously defined [5].

The maximum likelihood supervised classification method helps us to detect the human developed areas. It further classifies the different man-made objects into classes such as roads, buildings and parking areas. This is also helpful for detecting every man-made object. fig. 1 presents the multispectral Ikonos image used for the classification.

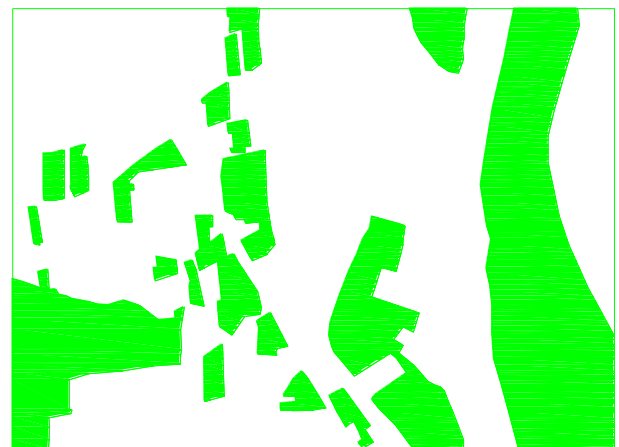


Fig. 3. Digitized vegetation land from paper map.

The result of the classified image is then filtered using median and sieve filters to remove noise and all polygons that are smaller than a given minimum size, measured in pixels. The level of filtering must be chosen adequately to remove small or isolated feature that may reduce the feature visibility.

After the classification process (by maximum of likelihood), sub-classes were aggregated to adapt the detected classes to the specified classes [2].

The classification contains many small, isolated groups of pixels within the larger single color areas. It is generally a good idea to incorporate these isolated pixels into the larger feature classes before performing a raster to vector conversion giving the image smoothing look. That way, vectorization, only vectorize the major features in the image and minimize the number of very small polygons that will be created [5].

The classified vegetation area was obtained from the maximum likelihood supervised classification method then three types of median filter is used to remove noise and the output as shown in fig. (4-6).

By visual comparison three types of median filter are compared to each other and the classified image with median filter  $5 \times 5$  found the best so it is selected for the following procedures.

In our case study there are two vegetation classes in this part of the image represented in green and light green. For this application, it must be aggregate these into one common class representing all vegetation before vectorizing them.

In raster to vector conversion, ER Mapper analyzes the boundaries of the features which was specified in a raster image, then traces polylines or closed polygons around the features. After vectorizing the features of interest, the output polylines or polygons can be saved to an ARC/INFO GIS coverage, or exported to other vector formats such as DXF [5].

The analysis of the two datasets (digitized map and IKONOS imagery) permits the detection and extraction of homogeneous topographic features to be compared at the information level. The detection of actual changes in these homogeneous vector spatial

patterns can be performed in an interactive or automated manner. The interactive approach is based on the superimposition of the extracted vector data from the image with either the map as background. In the automated approach using the vector data in a GIS system, the change is defined as the nonintersecting of the old and new vector features between two temporal spatial states (S1 and S2). The changes consist of deletions. A deletion is the difference between the old state and the common elements between the two states [2].

The classified image with filter  $5 \times 5$  was vectorized fig. 8.

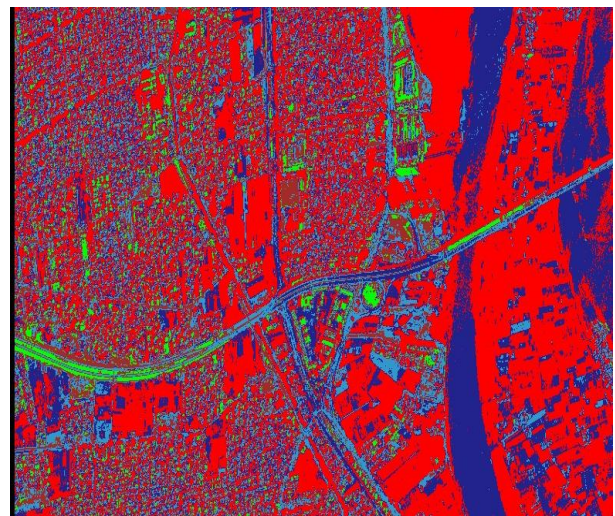


Fig. 4. Classified image without filter.

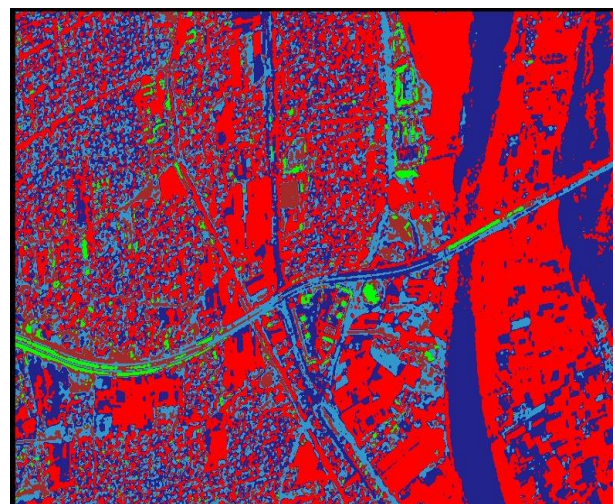


Fig. 5. Classified image with median filter  $3 \times 3$ .

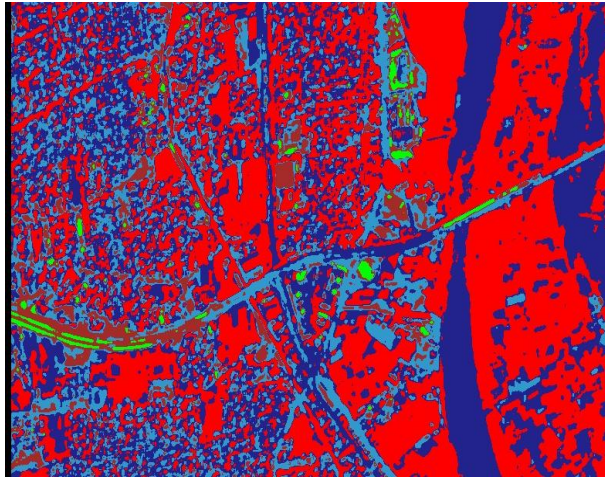


Fig. 6. Classified image with median filter 5x5.

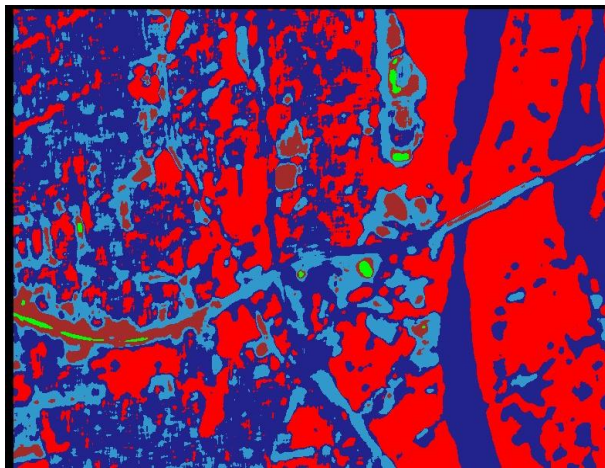


Fig. 7. Classified image with median filter 11x11.

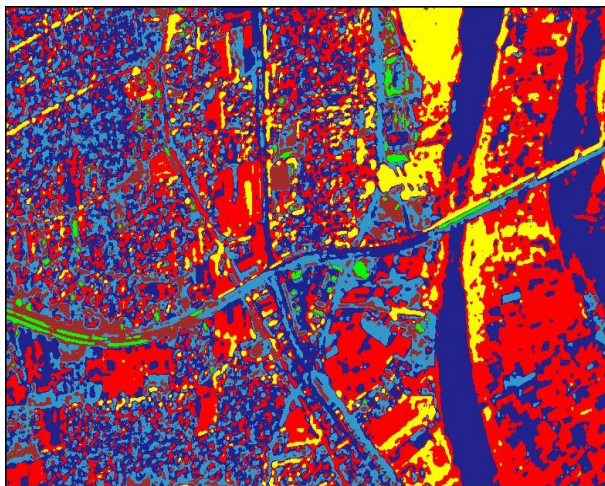


Fig. 8. Vector classified image with median filter 5x5.

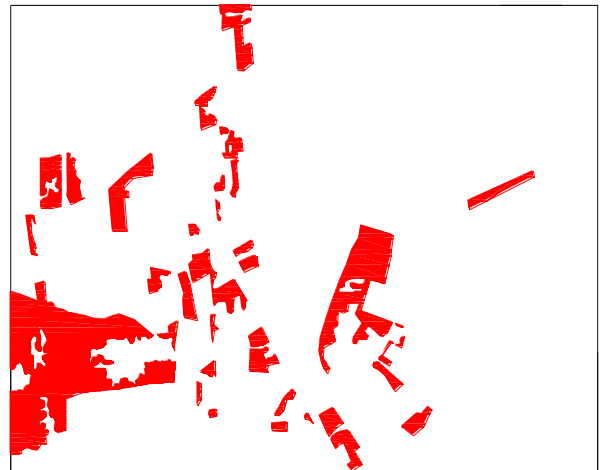


Fig. 9. output of overlay between vector classified image and vector map.

Then it is compared to the green area layer of the GIS data for the change detection. As shown in fig. 9.

Overlay operations create a new coverage by computing the geometric intersection of two coverages - an input coverage and overlay coverage.

The Input coverage can be a point, line, or polygon coverage. The Overlay coverage is always polygon coverage.

The Output coverage has rebuilt topology.

The Erase overlay creates a new coverage by overlaying the polygons of the Erase coverage with the features of the Input coverage. Only those portions of the Input coverage features falling outside the erase polygon outside boundaries are copied to the output coverage [6].

#### 4. Discussion and conclusions

Paper maps have always been of prime importance in the field of surveying. In today's society there is a greater emphasis on digital data than on paper maps. This corresponds to the proliferation of GIS in industry and in the research environment which has led to the need to convert all of the available analog geospatial data to digital form. Although the topological maps can be digitized or scanned, they cannot be used directly in a GIS system without processing, and therefore, require an

operator. Thus the main objective of this research was to suggest a methodology for feature extraction from satellite imageries using vectorization of satellite image.

Some of the applications that would benefit from this research are:

1. Geospatial Information Systems: Digitizing, Updating, etc.
2. Remote Sensing: feature extraction in satellite imagery, change detection, etc.

The various approaches and methodology developed and implemented within a GIS environment along with examples, results are presented and discussed.

This updated GIS data is useful for the city planning, property evaluation and taxation, among other purposes.

The research examined the use of very high resolution images for buildings extraction and changed detection.

Traditional change detection methods such as the post supervised classification technique have been implemented. The supervised classification method is found suitable for change detection of man-made objects such as buildings.

The results show that the system can aid in updating existing GIS data by interpreting images automatically.

The demand for rapid mapping operations such as database generation and updating is continuously increasing for mapping organizations. Due to the increased use of raster data, image processing techniques have been investigated and tested in this study to introduce automation in the process of detection and extraction of certain topographic features. The extracted topographic features were used for the change detection requirements. In our study, the separation and extraction process of features from the IKONOS image of Cairo were based on similarity of pixel values using image analysis techniques such as classification.

As the two data sets were not originally homogeneous, the comparison for the detection of planimetric changes was performed on vectorized data extracted from both data sets. Having defined and pre-processed the data sets for the epoch comparison, the actual change detection was performed of old and new features.

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